TERRA

Transportation Engineering and Road Research Alliance

# 15th Annual TERRA Pavement Conference: Session Summaries

February 10, 2011

University of Minnesota
St. Paul Campus

Sponsor:
Transportation Engineering and Road Research Alliance

In Cooperation with:
Center for Transportation Studies, University of Minnesota
Department of Civil Engineering, University of Minnesota
Minnesota Local Road Research Board
City Engineers Association of Minnesota
Minnesota County Engineers Association
Minnesota Department of Transportation
Minnesota Local Technical Assistance Program
American Public Works Association–Minnesota Chapter
Minnesota Street Superintendents Association

Facilitated by:
College of Continuing Education, University of Minnesota

## Conference Planning Committee

Jerry Geib, Minnesota Department of Transportation
Lori Graven, College of Continuing Education, University of Minnesota
Jim Grothaus, Center for Transportation Studies/Minnesota LTAP, University of Minnesota
Maureen Jensen, Minnesota Department of Transportation
Lev Khazanovich, Department of Civil Engineering, University of Minnesota
Sue Lodahl, Minnesota Department of Transportation
Bill Lohr, Federal Highway Administration
Erland Lukanen, Minnesota Department of Transportation
Stephanie Malinoff, Center for Transportation Studies, University of Minnesota
Mark Maloney, Engineering Department, City of Shoreview
Mihai Marasteanu, Department of Civil Engineering, University of Minnesota
Roger Olson, Minnesota Department of Transportation
Thomas Ravn, Minnesota Department of Transportation
Gene Skok, Department of Civil Engineering, University of Minnesota
Linda Taylor, Minnesota Department of Transportation
Joe Thomas, Minnesota Department of Transportation
Curt Turgeon, Minnesota Department of Transportation
Dave Van Deusen, Minnesota Department of Transportation
Rick West, Otter Tail County

## Production

Minnesota LTAP
Writing: Richard Kronick (freelance), Pamela Snopl
Editing: Pamela Snopl
Design: Karen Melton, Cadie Wright Adhikary

The **Minnesota Local Technical Assistance Program** is part of the Federal Highway Administration's Local Technical Assistance Program (LTAP). LTAP is a nationwide effort designed to foster and improve information exchange among local practitioners and state and national transportation agencies. Minnesota LTAP is administered by the Center for Transportation Studies at the University of Minnesota and cosponsored by the Minnesota Local Road Research Board and the Minnesota Department of Transportation.



**Minnesota LTAP**
Center for Transportation Studies
University of Minnesota
200 Transportation and Safety Building
511 Washington Avenue S.E.
Minneapolis, MN 55455
Phone: 612-626-1077
Fax: 612-625-6381
E-mail: mnltap@umn.edu
Web: www.mnltap.umn.edu

# Contents



## Conference Materials Online

PowerPoint presentations and selected video from the 2011 TERRA Pavement Conference are online at www.terraroadalliance.org/events/pavementconf/2011.

TERRA, the Transportation Engineering and Road Research Alliance, is a dynamic partnership of government, industry, and academia that continuously advances innovations in road engineering and construction. TERRA's mission is to develop, sustain, and communicate a comprehensive program of research on pavement, materials, and related transportation engineering challenges, including issues related to cold climates.

**2011 Rohrbach Award recipient Rick West: passion for a job well done**

In keeping with tradition, Mike Robinson, the 2010 recipient of the Gerald Rohrbach Award for Excellence in Pavement Research, presented the 2011 award. Robinson began by talking about how inspirational it had been to work with Rohrbach at the Mn/DOT Office of Materials and at MnROAD. Robinson said one way Rohrbach inspired him was through his passion for his work.

When the 2011 recipient—Rick West, the county engineer of Otter Tail County—was asked for his thoughts about civil engineering, he started the same way: "I've learned a lot from folks who have been in the trenches for a long time, people who are dedicated and have passion for what they do. I've always felt the same way. I have a passion for a job well done."

West said the first recommendation he would make to a younger county or city engineer is to "develop a good relationship with your county board or city council. If they value your abilities and recommendations, you can do a lot of great things," he said. "But building that relationship does not happen overnight. When you appear before them, you need to make the very best recommendation you can. And if they don't adopt your recommendation, don't take it personally. As long as you know you did the best you could, it is what it is! And if you feel passionately about it, maybe in six months you can take another run at it. Over time, I think boards recognize it if you are in fact providing them with the best possible recommendations. And if you continue to do that, you will build that relationship."

One of the people Rick West has mentored over the years is Freeborn County Engineer Sue Miller. Miller says, "When I was starting out, I met Rick at a conference, and he said, 'If you ever have a question, give me a call.' And I did call to ask how he handled various things in his county. Rick has a quiet, well-thought-out way of suggesting how to approach an issue. He does his homework. Gravel road maintenance is a good example of that. Rick has become an expert at it, in part because he's been teaching it for years. He has tried various strategies for dust control, for gradations, and so on. He knows what he's talking about."

Mike Robinson, Rick West

In addition to being an informal mentor to many civil engineers and an LTAP instructor in gravel road maintenance, West has held every office in the leadership of the Minnesota County Engineers Association. He also is the current chair of the Local Road Research Board. He has been a county engineer in Minnesota for 24 years.

# Morning Plenary Session

Moderator: Dan Wegman, Road Science LLC and TERRA industry co-chair

## Smoothness of Roads Research Customer Summary

Karla Rains, Minnesota Department of Transportation

Karla Rains discussed the results of several Mn/DOT studies conducted to learn what the driving public thinks about the condition of Minnesota's roads.

One of these, an annual Omnibus Tracking study, has been collecting data on some measures dating back 20 years; it collected data as recently as November 2010. Rains said participants gave very high ratings on issues such as signage, snow and ice removal, and striping. On the issue of pavement smoothness, however, the average score (on a scale of 1 to 10) fell from 6.6 to 6.0 from 2005 to 2009—statistically significant, she said. Then scores crept back up to about 6.2 in 2010. She also said the smoothness ratings correlate closely with responses to a summative question about overall maintenance for roads.

The findings indicate that attitudes about smoothness are a major contributor to the public's overall thinking about Minnesota roads, Rains said. However, while the study provides useful numerical scores of the public's perception on pavement smoothness, "It doesn't always tell us why they're saying what they're saying," she said. As a result, two additional studies were conducted to gather more in-depth (qualitative) information from the public to help Mn/DOT understand these scores.

One of these involved a group of 600 Minnesota citizens chosen to closely represent both genders and a wide range of ages, incomes, and geographical locations. In 2010, these people responded to weekly online questionnaires on a range of transportation issues.

Using this group, a further study was done to gain a clearer idea of what citizens mean when they say a road is "smooth" or "rough." The 600 subjects were shown visual images of pavements gathered from Mn/DOT's Materials and Road Research Office. Using the Ride Quality Index (RQI) scale (in which pavements are rated from 0 to 5), each subject was asked to rate 14 images of pavements with progressively worse condition. When shown the series of 14 photos, participants successively downgraded their ratings as they progressed through the series. However, when comparing the RQI ratings with the customer ratings (though this same pattern holds), customers tended to rate more harshly (from visuals alone) than the RQI—that is, "fair" and "poor" descriptors were used earlier in the continuum.

An additional study was done in the hope of further calibrating the public's perceptions of ride quality. In 2010, 46 people were recruited (and each paid $75) to participate in a "ride-along" study. All rode the back seat of cars that were driven over the same 31 road sections, each about a half mile long. The sections included mostly freeways and highways and a mix of asphalt and concrete surfaces. All subjects rode in the same six state cars of the same make and model. Tire pressure was also checked and kept constant. Cars left the Mn/DOT Maplewood facility in caravans. Mn/DOT employees rode in the cars and acted as announcers, alerting the citizen raters as each test section approached and when it ended. As a comparative, RQI was measured on the same sections by a Mn/DOT van the same day.

Rains said alignment of citizen scores and mechanically derived scores was "surprisingly close." The mean (composite) citizen score was 3.2 and the mean van-derived score was 3.3. Citizens also responded to questions about whether each section was "in need of repair" and "acceptable or unacceptable." Not every section deemed in need of repair was also rated unacceptable. "This tells us that we need to be clear in our communications with customers," she said. "We know what needs to be done to extend the life cycle of a pavement, but they, of course, do not. They may say,

'Oh, it might be good enough' and explained that they were thinking about reduced government budgets. We need to explain to our taxpayers why we do what we do to preserve the infrastructure and manage our long-term repair costs."

Rains also commented that there was a very high level of enthusiasm for the study: "People were glad and appreciated being involved."

Summarizing the studies, Rains said that although road-smoothness customer ratings continue to be the lowest of all the maintenance services Mn/DOT provides, customer confidence in the department's "ability to do a good job at maintaining roads and bridges" is improving.

Mn/DOT will continue to track customer road-related perceptions and expectations, Rains said. She also noted that the "ride-along" results reported reflect road conditions in the Twin Cities only and may not reflect road conditions and perceptions in Greater Minnesota, and she recommended a study be replicated in areas throughout the state.

# The Future of Pavement Technology

Joe Mahoney, University of Washington

Professor Joe Mahoney talked about several aspects of the future of pavement technology.

**Online design tools**

Mahoney predicted a proliferation of online pavement design tools—and as an example showed a few screen shots from one he has been working on. It is a product of the SHRP2-R23 project, "Using Existing Pavement in Place and Achieving Long Life" (http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2174).

In the tool, "long life" is defined as 50 years; Mahoney said this refers to the pavement structure, not necessarily the wearing course. Like other online design tools, the one shown by Mahoney allows the user to input basic data such as traffic and the existing pavement structure, and then suggests alternatives to reconstruction. It also includes guide specifications, has links to numerous online resources, and summarizes specifications from AASHTO and several state DOTs. The tool is scheduled for completion in October 2011.

**The cost of transportation**

Mahoney presented statistics on the costs of various transportation initiatives and concluded that not enough money is being spent on pavement research. Then he reviewed the results of a survey by Booz Allen Hamilton on R&D spending in various sectors of the U.S. economy:

- Average among many industrial segments (e.g., automotive, pharmaceutical, computing): 4.2%
- Microsoft: 21%
- Oracle: 12%
- FHWA: 0.5%
- State DOTs (average of 25 surveyed in 2008): 0.1% to 0.2%

Table 1. Training session attendees in California (numbers rounded)

| | Asphalt Pavement Fundamentals | Asphalt Mix and Structural Design | Concrete Pavement Fundamentals |
|---|---|---|---|
| Caltrans engineers | 45% | 75% | 90% |
| Local agencies (cities and counties) | 40% | 15% | 4% |
| Special authorities (port, bridge, etc.) | 5% | 5% | 1% |
| Private consultants | 5% | 5% | 5% |
| Contractors and materials suppliers | 5% | 1% | 1% |

Mahoney concluded this discussion by asking, "Is it any wonder that we don't make faster progress [on pavement construction and maintenance]? We just don't spend enough money."

He also noted that the statement might appear to be a bit self-serving since he does funded research, but the numbers back his view.

**Training improvements**

Next, Mahoney turned his attention to pavement-related training. He showed results from a 2002 Transportation Research Board study on who attends training sessions in California on three topics: HMA basics, PCC basics, and Asphalt Mix and Structural Design. Table 1 summarizes the percentage of total attendance.

"I understand the low attendance from private companies," Mahoney said, "but I see it as unfortunate."

He then predicted that online learning will be a growing part of the solution. As an example, he showed screen shots from Pavement Interactive, a "wikipedia for pavement engineering" developed by several agencies including Mn/DOT. Pavement Interactive was consulted over the last 12 months by about 2,000 unique users per day from about 13,000 cities worldwide, according to Google Analytics. "This suggests the power of online tools," Mahoney said. Furthermore, using Table 2, he demonstrated that online training is much less costly than other modes of training.

Pavement Interactive home page

Mahoney summarized his thoughts by answering four questions:

- Are we spending enough on pavement preservation? NO
- Are we spending enough on research and development? NO
- Do we have the "right" mix of training and training resources? NO
- Are we doing a proper mix of research? NO

So, he asked, are we going to do anything about these "no" answers?

Table 2. Costs of online training

| Training Type | Cost Per Minute |
|---|---|
| Two-day short course ($400 course) | $0.42 |
| Two-day short course plus attendee salary (assumes $65/hour pay rate) | $1.42 |
| Traditional college courses (ignores value of student time) | $0.03 to 0.15/minute |
| Online college courses (ignores value of student time) | $0.05 to 0.10/minute |

# Afternoon Plenary Session: Sustainability in Transportation

Moderator: Maureen Jensen, Minnesota Department of Transportation

## FHWA's Sustainable Highways Self-Evaluation Tool

April Marchese, J.D., Federal Highway Administration

April Marchese, director of FHWA's Office of Natural and Human Environment, discussed a new tool under development by her office. Called IN-VEST (Infrastructure Voluntary Evaluation Sustainability Tool), the Web-based tool can be used by public agencies to assess the sustainability of transportation projects. The tool is now in a beta version and available at www.sustainablehighways.org.


www.sustainablehighways.org

Marchese said FHWA's goals in developing the tool are to:

- Encourage sustainable highway practices.
- Help agencies measure sustainability and quantify tradeoffs.
- Provide a framework for communicating with stakeholders about sustainability.
- Establish a method for evaluating sustainable highways.

IN-VEST is based on existing tools, such the U.S. Green Building Society's popular LEED (Leadership in Energy and Environmental Design) program and similar programs designed specifically for transportation projects by the New York State DOT (https://www.nysdot.gov/programs/greenlites) and Washington State DOT.

Marchese defined a sustainable transportation project as one that:

- Satisfies functional requirements.
- Addresses development and economic growth.
- Reduces impact on the environment and on the consumption of resources.
- Addresses sustainability from planning through operations.
- Addresses environmental, economic, and social equity dimensions.

She emphasized that the program is "not just about protecting the environment—you have to weigh economic and social costs as well." She used the diagram in Figure 1 to suggest a "triple bottom line" for sustainable transportation projects.

She also emphasized that the program is voluntary and that there are no plans to mandate the use of the tool or to make its use a condition of funding. However, she did say there are plans to develop an awards component to promote use of

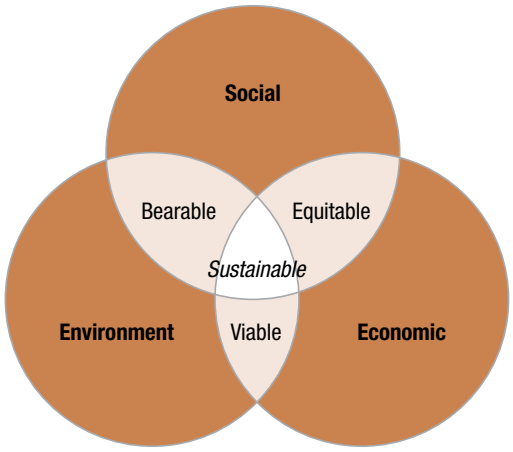


Figure 1. The "triple bottom line" for sustainable transportation projects

the program.

IN-VEST's rating system, which defines 68 credits that can be earned by a highway or other transportation project, is organized to reflect the three major phases of a project:

- Planning. For example, a project receives credits if it includes a cost-benefit analysis or if it includes an initiative to educate the public on the sustainability aspects of project.
- Development and implementation. For example, a project receives credits if it includes use of recycled materials, pays attention to site vegetation, or provides pedestrian access.
- Maintenance and operation. For example, a project receives credit if it includes a pollution prevention plan, a pavement management system, or a plan for roadside infrastructure maintenance.

Marchese said scoring within the rating system emphasizes safety and is based on three principles:

- The effectiveness of the sustainability measure
- The longevity of the benefit
- The value (environmental, economic, and/or social) of the sustainability benefit

She invited comment from the transportation community on the system's current beta version and said her office plans to release vetted and expanded versions in the spring and fall of 2011.

# Trends in Climate Change that Affect Road Construction and Maintenance

Mark Seeley, Department of Soil, Water, Climate, University of Minnesota

Mark Seeley, the University of Minnesota's well-known professor of meteorology and climatology, gave a clear message: "The Great Lakes region, including Minnesota, is experiencing a profound climate change—and we need to think about how to adapt to it."

**Minnesota: a state of extremes**

Seeley began by listing some of Minnesota's all-time weather extremes:

- In 1936, the state experienced a temperature range of 169°F. The temperature reached –55°F on February 11 of that year and also 114°F that summer. "There are not many points on earth that experience that kind of variation," Seeley commented.
- In both the 1991 Halloween blizzard and the 1940 Armistice Day Blizzard, we experienced snowfall rates of 3 inches per hour.
- We've had 98 mph winds—hurricane force!
- We've had 60-hour storms.
- We've had windchills as low as –71°F. In 2001, Seeley said, the windchill scale was changed to more accurately reflect what the human face feels. Prior to that date, our state windchill record was –108°F. Now the maximum possible windchill is –71°F.
- In the winter of 1996–97, when 14 blizzard warnings were declared, Mn/DOT's total cost for snowplowing and removal was more than $250 million. Seeley referred to the National Weather Service's official definition of a "blizzard," which can be found at: http://web.archive.org/web/20050829022450/http://www.crh.noaa.gov/mpx/nwseventdef.html. In fact, as shown in Figure 2, Seeley said Minnesota is the North American bulls-eye for blizzards. In any given year, there is a 50 to 76 percent probability that a blizzard will strike our state.

**Shorter winters**

After dazzling the conference attendees with these extremes, Seeley came to his main point: Minnesota and the rest of the Great Lakes region are experiencing climate change. To support that contention, he presented data for both winter and summer that have been gathered from hundreds of professional and volunteer statewide observers.

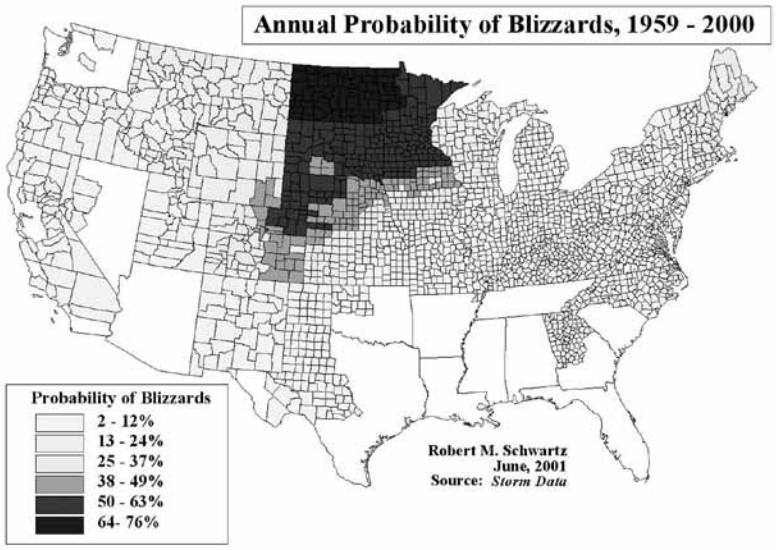


Figure 2. Annual probability of a blizzard by county, 1959–2000 (source: Robert M. Schwartz)

In the winter months, he said that on a statewide basis, since 1997:

- We have had fewer blizzards.
- Nearly every location in the state has had fewer days with measurable snow.
- But there have been more days with 4 inches or more of snow—so when we do get snow, we get more of it at once.
- Unfortunately for pavement maintenance budgets, there have been more freeze-thaw cycles than at any other time in the state's climate record, going back to 1880.

He added that our winters are getting shorter. Since the 1980s, winter comes later and spring comes earlier. As a result, January has surpassed March as our snowiest month simply because more of March precipitation is now liquid rather than frozen. In 2010, he reminded the audience, our state had an early and sudden spring, leading to the earliest corn-planting season in our history. If we have another early, sudden spring this year, he warned, "we will have flooding in every watershed in the state."

**More and more rain—for 3,000 years!**

Seeley showed equally disturbing trends for Minnesota summers. "We used to get about 60 percent of our total annual precipitation from thunderstorms. But since the 1980s, it's about 70 to 75 percent," he said. "This is a problem for farmers, for road building and maintenance, and for storm sewer runoff systems." In the past 20 years, on an annual basis, we have received more rain than ever before—and southern Minnesota has been hit the hardest. He provided these examples:

- Since 1991, the town of Winnebago, in Faribault County, has had 40 occurrences of rainfall of 2 inches or more—including an 11-inch rainfall on September 22–23, 2010, that produced one of the largest flash floods in state history.
- The town of Hokah, in Houston County, had 24 inches of rain in August 2010.
- There have already been three large flood events in southern Minnesota since 2000 that are outside the bounds of the state climatology office's "historic occurrence calculations." All have caused great damage.

Seeley also noted consistent increases in precipitation since the dustbowl days of the 1930s. In 2010, our wettest year in history, the state had an annual rainfall average above 34 inches for the first time ever, he added.

Seeley then put an exclamation point on the rainfall data by discussing a 2010 paper published by members of the University of Minnesota's Department of Geology and Geophysics.[1] By studying the layers of stalagmite formation in Spring Valley Caverns (Fillmore County), they concluded that Minnesota's rainfall has been on a general upward trend for the past 3,000 years.

Coming back to the modern era, Seeley added that "even though the state as a whole will continue to be wetter, we will continue to have some regions—notably northeastern Minnesota—in severe drought. Lake and Cook Counties have had droughts every year since 2005, so the disparity across the state is greatly amplified."

Seeley then showed that while our rainfall has gone up, our summer high temperatures have generally gone down. For example, the number of 90°F or higher days in the Twin Cities has steadily declined since 1945.

But, he added, "In the same time frame, the water vapor content is on the rise; we're having more days with 70-degree dew points. Previously, that was characteristic of 30 degrees north latitude rather than 45 degrees [the latitude of the Twin Cities]."

[1] S. Dasgupta, et al.: *Earth and Planetary Science Letters*, 300: pp. 46-54, 2010.

While overall temperatures are going down, he explained, overnight minimum temperatures are going up: "Before 1996 there was never an 80-degree dew point in Minnesota. But since then, we've had those dew points all over the state—with several occurrences in our northernmost counties. This gives us a higher heat index. Most of the heat waves in Minnesota from 1883 through about the middle of the 20th century were caused by high temperatures. But since then, most of the heat waves were caused by high dew points—not temperature. And that's not happening only in Minnesota; it's the trend throughout the Great Lakes region including Manitoba."

**Adapting to climate change**

Seeley predicted that, statewide, we will continue to have:

- More intense thunderstorms with large hail.
- More flash floods.
- More heat advisories as a result of high dew points.

"The data tell us the climate is changing," he concluded. "We may debate the causes, but to be good citizens, we need to accept it. And I'm speaking for all of the climatologists in our region. We all agree. So it's important to factor this into your work and your perceptions of the world around you."

In response to questions about what can be done, he provided some examples of how we are already adapting: "Some places have increased the size of their runoff systems to handle the increased precipitation. Some farmers have installed controlled drain tile systems, so they can retain water when they need it and get rid of it when they don't. We are already doing these things to adapt. We need more knowledge—and then more discussion about ways to respond to these trends."

Seeley was then asked to comment on global warming. "It's far too often portrayed in an overly simplified way and far too often politicized," he said. "But I believe it's real. It's in evidence on all continents. It's more striking in the mid latitudes than in the high latitudes. The drivers—the reasons behind it—include natural variability that has happened over billions of years, changes in landscape and land use, and emission change—that is, changes in the composition of the atmosphere. But I don't think we have the knowledge base to differentiate among these. Maybe one day we will have that."

As his final example, he said that, in August of 2010, the town of Churchill, on the southwest coast of Hudson's Bay, recorded its very first thunderstorm ever. "That's scaring the daylights out of the Canadian climatologists."

Heavy rains and flooding are becoming more common—like this example north of Henderson, Minnesota, in fall 2010. (photo: Brian Sorenson)

# Concurrent Sessions

## Session 1: Innovation in Construction Practices

Moderator: Mark Maloney, Public Works Department, Shoreview, Minnesota

### PG XX–34 and Transverse Cracking

Erland Lukanen, Minnesota Department of Transportation

Erland Lukanen reported on a recent study that found less transverse cracking with -34 performance-graded binders.

Mn/DOT started using performance-graded binders in 1997, he said. The intent is that binder properties should be selected considering traffic and climate.

PG binders came out of a Strategic Highway Research Program (SHRP) asphalt study that produced the Superpave mix design methodology and performance-graded binder tests and specifications. Mn/DOT set its current criteria in 1999:

- PG 64-34 on high-volume new construction
- PG 58-34 on low- to moderate-volume new construction
- PG 58-28 or 64-28 for overlays

Mn/DOT rates the condition of higher-volume pavements every year and the rest of the system every other year, Lukanen said. It counts transverse cracks in the first 500 feet of each mile by severity: low, medium, and high. However, the pavement management system did not contain PG information.

A transverse crack

In this study, Bituminous Office records were used to find projects that used PG binders with -34°C grading on new construction. Twenty-six new construction projects were found from 2000 to 2007. New construction consisted of new asphalt over an aggregate base; full-depth reclamation projects had new asphalt over the reclaimed material. The study found that use of PG binders reduced transverse cracking.

### Intelligent Compaction for HMA

Greg Johnson, Minnesota Department of Transportation

Greg Johnson discussed two projects in 2010 that used intelligent compaction—TH 169 in northcentral Minnesota and TH 13 in southern Minnesota.

He began by describing the relationship between temperature and density differentials. A Washington DOT study from 1998–2001 found that an increasing temperature differential during mix placement corresponds to increasing air voids, which in turn affects pavement performance. A Mn/DOT study from 2001 found that profiles with a difference greater than 25 degrees had a 50/50 split on passing and failing densities; profiles with a difference less than 25 degrees had 93 percent passing the density requirement.

A new technology, the MOBA Pave-IR, uses infrared sensors to produce a continuous thermal profile, he said. It delivers real-time data to the operator on a touch screen. The Texas DOT plant-mix asphalt specification uses the data to evaluate thermal segregation during construction. Infrared cameras had been used before to collect

thermal data, but the Texas Transportation Institute and Texas DOT refined infrared methods by developing an infrared temperature bar and an accompanying data collection and processing software package. Pave-IR was commercialized by MOBA, a German company.

(More about the Pave-IR: *Pilot Implementation of Pave-IR for Detecting Segregation in Hot-Mix Asphalt Construction*, http://trid.trb.org/view.aspx?id=778719; "An Incentive To Take Asphalt's Temperature," *Engineering News Record*, August 18, 2010, http://texas.construction.com/features/2010/0701_NewSystemMonitors-1.asp.)

Intelligent compaction roller and display systems collect GPS coordinates, mat temperature, number of passes, and material stiffness. The results include significant improvements in rolling patterns—and thus consistent products, Johnson said. Other benefits include improved density, improved efficiency, and increased information—overall, improved pavement performance.

An intelligent compactor (photo: Greg Johnson)

## Granular Material Selection for Best Value Pavement Performance

Erol Tutumluer, University of Illinois

A MnROAD study found that the backcalculated base moduli of Mn/DOT Class 3 aggregates were often greater than those of higher classes. This surprising field evaluation finding indicates it may be challenging to know how to best use locally available aggregate materials in road bases and subbases, Erol Tutumluer said.

He described a research project intended to demonstrate that locally available materials can be both beneficial and economically efficient in implementing the available mechanistic-based design procedures in Minnesota through the MnPAVE Mechanistic-Empirical Pavement Design Method.

The goals of the project are:

- Develop the components of a new best-value software module for granular material to be added to the MnPAVE program.
- Provide pavement designers with index aggregate properties linked to modulus and strength characteristics.

Ultimately, he said, the expected benefit of the project is more economical and effective use of locally available aggregate materials in Minnesota.

# Session 2: Alternatives to Paving: Unpaving and Light Surfacing

Moderator: Rick West, Otter Tail County, Minnesota

## Alternatives to Paving to Carry Heavy Loads

Ken Skorseth, South Dakota Local Technical Assistance Program

An important session at this year's annual TERRA Pavement Conference focused on "un-paving"—the practice of converting an asphalt-surfaced pavement to a gravel-surfaced one. The session included presentations by Ken Skorseth of the South Dakota LTAP and Professor Joe Mahoney of the University of Washington.

Skorseth began by referring to the distastefulness of the topic: "I tried to put a positive slant on this topic by calling my presentation 'alternatives to paving' rather than 'un-paving.' Maybe that softens it a little bit. But the fact is, it's a bitter pill to swallow. In the glory days, right through the mid-70s, we were building pavements. In those days, I never dreamed I'd ever be talking about un-paving."

He said this issue wouldn't exist if it weren't for the combination of two factors: increasingly heavier loads, and pavement design standards that have not kept up with those loads. Currently, many western states including South Dakota have no limits on vehicle weight or on the number of axles a vehicle can have. Furthermore, Skorseth said, "Vehicle size is growing right at the time when many of these pavements are reaching the ends of their lives."

Heavier loads are causing problems on local roads. (photo: cjberry)

Like it or not, there is a need for knowledge about alternatives to paving—and Skorseth assessed several strategies:

- Back to gravel
- Stabilized gravel
- Thick base with asphalt surface treatments, including BST (chip seal) and Otta seals

**Back to gravel? Be careful!**

Skorseth cited an SDDOT study (http://apps.sd.gov/Applications/HR19ResearchProjects/oneproject_search.asp?projectnbr=SD2002-10) published in 2004 that looked at the 20-year life-cycle costs of 120 road sections in 26 South Dakota counties. The pavements were of three surface types:

- Gravel
- BST (bituminous surface treatment; i.e., prime coat + chip seal on aggregate base)
- HMA

The study found that the life-cycle cost of gravel-surfaced roads increases sharply with ADT. Because of this, Skorseth said, gravel-surfaced roads are only suitable up to about 170 ADT. If user costs are included, he added, the break point moves down to 150 ADT. "Most of these user costs are related to loss of fines," Skorseth said. "Especially in a semi-arid climate [such as parts of western South Dakota], dust causes accidents and loss of aggregate, which in turn requires addition of material and increased blading."

The life-cycle cost of BST-surfaced roads (primer and chip seal on aggregate) increases almost as steeply as gravel-surfaced roads. As a result, Skorseth said, the effective limit for BST

surfaces is 650 ADT.

In comparison, the cost of HMA starts high but increases the least steeply of all, making it the most suitable surface for ADTs above 650. (Note: Professor Joe Mahoney, whose presentation is discussed in more detail on page 12, stated that current Washington State policy is to use gravel-with-chip-seal surfaces on roads that carry up to 5,000 ADT.)

Skorseth warned that there are additional reasons to question the conversion of HMA surfaces to gravel: "The quality and availability of gravel vary greatly in some places, including South Dakota." He added that, if truck traffic is 25 to 50 ADT and there is low subgrade support, which he defined as CBR ≤ 3%, the gravel layer will need to be at least 14.5 inches thick. "That's hard to maintain when trucks are knocking it off constantly and the blade needs to be out there every other day."

**Stabilized gravel**

Turning to roads with stabilized gravel surfaces, Skorseth summarized SDDOT's observations of three roads:

- A high-quality South Dakota gravel road stabilized with annual chloride treatments has held up very well since 1998. The road is used by seven-axle concrete trucks at a rate of 80 ADT. Less than 200 tons of additional gravel has been needed in 12 years.
- In 1989, 8 inches of gravel was placed on a road in the Black Hills region, and, in Skorseth's words, the road was "aggressively reshaped." The road carries 1,000 ADT. Since 1998, it has been treated annually with liquid magnesium chloride. In the ensuing 12 years, a total of 4 inches of gravel has been added. Visual inspection suggests little environmental effect. The cost of annual treatment, gravel replacement, and blading has averaged $3,600 per mile per year for five years.
- A road in Richland County, Montana, receives heavy traffic from agribusiness and oil and gas development. (Montana places no limits on the size or configuration of trucks.) The problem for this road is the limited availability of gravel. "The base," Skorseth said, "is crushed gravel, but the fines are non-plastic. Their solution is to mix Bentonite™, a highly plastic clay, into the top 3 inches of an 8-inch gravel layer. They call it 'poor man's pavement.'" He warned that Bentonite is a dangerous material. "If you get too much on your tires, the tires swell up until the vehicle stops. And when one driver held the accelerator down, it took out the transmission!" In the same location, tests are being conducted on prototype equipment for accurate application and mixing. They also have experimented with calcium chloride—both applying it to the surface and mixing it into the top layer. Initial performance has been excellent.

The life-cycle cost of gravel-surfaced roads rises sharply with ADT.

**Surface treatments and Otta seals**

Skorseth discussed two other case studies involving surface treatments. First, he showed a road in Davison County, South Dakota, that carries up to 150 trucks a day. It was reconstructed in 2007 with geotextile, 12 inches of base gravel, and a BST surface. At that time, the plan was to place 4 inches of HMA in 2009, but when the time came the overlay was not done due to budgetary considerations. Skorseth said the BST surface remains and is now showing flushing distress. "I'm surprised it lasted this long!" he added.

Finally, Skorseth discussed a road in Pierre, South Dakota, that has been treated with Otta seal. The road carries 375 ADT—about 30 percent of which are trucks. "Since there's no strength in the surface," he said, "all of the strength must be in the base. This road has performed well so far, but a road like this could require as much as 20 inches of base." Although a well-known Iowa study reported a 1-ton loss of gravel per vehicle per day, he added, "that's too general; there are too many variables."

## The Cost-Effectiveness of Bituminous Surface Treatments

Joe Mahoney, University of Washington

**Washington State strategies**
Professor Joe Mahoney presented information on paving alternatives in Washington State. Like Skorseth, he lamented that—only because of budget reductions—many HMA-surfaced pavements in Washington must be converted to BST surfaces.

**Cost of BST**
The cost of building a lane-mile of BST is about $25,000, Mahoney said. "This value might appear high," he added, "but it is a loaded cost. It includes contractor costs, taxes, traffic control, WSDOT inspection, and testing."

**Check for top-down cracking**
Mahoney emphasized the importance of checking for top-down cracking on HMA-surfaced pavements before converting them to BST surfaces. He also discussed research from several worldwide sources, including MnROAD, showing that chip sealing soon after construction significantly reduces aging in HMA binders.

**Continuous improvement**
Mahoney discussed an initiative that he has organized in Washington to improve paving practices. Each year since 2006, he has hosted and moderated a workshop with representatives from WSDOT and paving contractors. "We put all issues on the table and invite everyone to offer their opinions. No decisions are binding on WSDOT. But in fact, these workshops have had an impact on numerous revisions of the standard specifications and BST practices." Mahoney summarized the lessons learned from these sessions:

- We need to have a BST design standard—especially important as aggregate payment by the square yard becomes standard.
- In the 2009 workshop, WSDOT favored aggregate payment by the square yard. Contractors: not so much.
- WSDOT policy for maximum amount of HMA level up is 70 tons/lane-mile.
- Maximum surface temperature for BST dropped from 140°F to 130°F in the 2010 specification.
- Control of the P200 is critical for successfully placed chip seals. Actual statistics show the average for WSDOT projects is about 0.9% P200.
- Two WSDOT regions fog seal their chip seals; some choke and fog to reduce snowplow damage.
- After chip seal, several Washington regions place 3/8-inch HMA on heavy-traffic intersections and report no more whipping rock off of intersections.
- BST is possible on 12 to 15 percent grades. "We can chip seal anywhere if we have good traffic control—and you have to pay good money to do that," Mahoney commented.

In closing, with the current downward trend in funding, Mahoney said, it is certain that more HMA-surfaced pavements will be converted to BST surfaces. But research shows that, if a pavement is structurally adequate, a BST surface can serve for many years—and that, with appropriate leveling of HMA surfaces before chip seal, good ride quality can be maintained.

# Session 3: In-Place Recycling: Best Practices

Moderator: Jerry Geib, Minnesota Department of Transportation

## Washington County's Experience with In-Place Recycling

Cory Slagle, Washington County Public Works

## Performance Evaluation of Asphalt Pavements with Full-Depth Reclaimed Base

Todd Thomas, Road Science LLC, and Shongtao Dai, Minnesota Department of Transportation

## Iowa's Best Practices for Full-Depth Reclamation and Cold In-Place Recycling

Scott Schram, Iowa Department of Transportation

The presenters in this session reported on many years of experience, lab results, and a wide range of projects.

- Cory Slagle of Washington County Public Works reported that his agency has done about 38 miles of cold-in-place recycling (CIR) and full-depth recycling (FDR) over the past 10 years.
- Scott Schram of Iowa DOT said his agency has done only a few FDR projects—but it has done 53 CIR projects comprising 1,800 lane-miles.
- Co-presenters Shongtao Dai of Mn/DOT and Todd Thomas of Road Science LLC provided a mid-term report on a project to assess FDR stabilized with various stabilizers, including fly ash and emulsion. This includes what may be the very first emulsion-stabilized FDR project on an interstate highway.

All the presenters agreed that CIR and FDR can be cost-effective methods for dealing with deteriorated pavements—and that these methods should be considered as alternatives to reconstruction, overlay, and mill-and-overlay.

**When and where are CIR and FDR appropriate choices?**

The presenters agreed that an agency should consider the following factors when deciding whether CIR or FDR are appropriate for a given section:

- **Existing pavement condition**. Slagle said Washington County's decision is based on the Pavement Condition Index (PCI). In general, the county uses CIR and FDR on roads with PCIs of 40 to 50 and below—poor condition.
- **Traffic volume**. Schram said IDOT's rule of thumb is to use CIR on roads that see 2,000 or fewer ADT. "But if it gets more than that," he said, "it doesn't mean we can't do it. In fact, we're trying to do more of it on high-volume roads. It can be successful, but we have to do our homework. We have to know the thicknesses and do DCP or FWD to assess the existing structure." Shongtao and Thomas designed the I-94 project as an accelerated test of FDR—3.5 million ESALs in five years.
- **Thickness of existing pavement**. It's important to take cores or do GPR to determine pavement thicknesses. The pavement might be either too thick or too thin for CIR or FDR.
- **Geotechnical evaluation**. The strength of the underlying material is crucial. Slagle: "If you find that the soil underneath is too soft, you shouldn't be doing either CIR or FDR. You probably need to replace unsuitable soils and reconstruct the pavement." Schram: "Typically we want to see 8 to 9 inches, with 3 to 4 inches of that being HMA. Using a dynamic cone penetrometer on the top 12 inches of subgrade, if you get fewer than four blows per inch, it's not going to work. If it's between four and six, it's marginal; above that it's likely

that CIR will work well."

- **Shoulders**. CIR or FDR plus an overlay will raise the pavement. If shoulders were already significantly below the pavement, it's important to factor in the cost of a shoulder overlay.
- **In-slopes on rural roads**. Slagle: "If you already have steep in-slopes and then you raise the road by 6 inches, it might be hard to hold the in-slopes with just gravel outside the roadway."
- **Drainage**. Slagle pointed out that it's important to consider potential run-off issues for the properties bordering the roadway. The combination of a raised pavement and a shallow ditch can be trouble.

**Appropriate for high volume?**

Shongtao and Thomas's project test on I-94 includes three test cells and their shoulders—with varying stabilizing materials. All were placed on MnROAD sections of I-94 in 2009. In addition, the researchers are monitoring six stabilized FDR sections on county roads throughout Minnesota. Their objectives are to:

- Study how an emulsion-stabilized FDR affects pavement performance in an accelerated loading scenario.
- Demonstrate viable rehabilitation options for flexible pavements.
- Demonstrate how stabilization is optimized based on quantity of RAP and depth.
- Evaluate additives—emulsion and fly ash—and check compatibility.
- Determine additive quantities and water ratios for various additives.
- Determine if add-rock or a secondary material is needed to change the gradation—either to increase thickness or to strengthen the material.

They are measuring granular equivalent (GE) as a way to assess the strengths of the pavements. The I-94 sections are now about half-way through their design life and holding up well. The researchers have observed no cracking and minimal rutting (< 0.2 inch). In addition, after removing a section of HMA overlay and stabilized base, they reported that the layers are adhering very well.

**Will CIR hold up to traffic during cure time?**

Schram: "When you delay the curing process, you also delay the overlay, which neither the contractor nor the public wants—but you have to wait for the CIR to cure. We've seen contractors add water to speed up the curing. But then they don't get sufficient compaction." Shongtao and Thomas said allowing traffic on CIR before overlaying is out of the question for I-94. But the other presenters said it works well for low- to medium-volume roads. For example, Slagle discussed a project on a 25,000-ADT road in Woodbury and said the CIR held up very well for two weeks before the overlay was placed.

**Foam or emulsion?**

Schram discussed IDOT lab research that shows foam delivers slightly better indirect tensile strength than emulsion, but for both foam and emulsion, moisture content and indirect tensile strength vary inversely.

Schram also discussed two other ways to compare foam and emulsion. He first showed IDOT lab results for "flow number," a way to characterize a pavement's susceptibility to rutting. These suggested that foam-stabilized CIR produces less rutting than emulsion-stabilized CIR—but he cautioned that these were results from only a few RAP sources, and results may vary with RAP from other roads. Then he showed comparisons of foam and emulsion for dynamic modulus; these also suggested that, once the moisture had stabilized, foam was somewhat superior to emulsion. Schram concluded: "In the end, emulsion's greater susceptibility to rutting may affect the traffic while you're waiting to overlay, but it's not going to affect long-term performance. The magnitude of impact is material dependent. The difference between foam and emulsion may be significant on one project and not on another."

**When should you place the overlay?**

Based on its research on moisture content, IDOT tentatively established an overlay trigger point of 1.5 percent moisture. However, it later found this to be impractical because projects were leveling off at 2 or 3 percent. "What's the point of having a spec," Schram said, "if you always get a phone call saying 'Hey, this thing's not changing; can we overlay?'—and we always say 'Yes'!" So IDOT raised the trigger point to 2 percent.

But recently it has been experimenting with a different approach: It is using a GeoGauge®, a portable device that measures pavement stiffness

to determine when to overlay. "After all," Schram said, "moisture content is just a surrogate for stiffness." The GeoGauge® is like a mini-FWD. It applies sinusoidal loading and measures deflection. He showed stiffness results for several sections and said this is a more useful trigger than moisture content. For example, he showed one project where moisture content leveled off in about 12 days, but the pavement's stiffness rose significantly beginning at about 20 days.

**Mix design is essential**

All presenters agreed that, once CIR or FDR has been chosen, mix design is the key to a successful project. Slagle: "Our construction guys like to say 'Just put 2 percent oil in and we'll hold it in our hand and figure out when the CIR is good.' But we went through a couple of CIR projects where the mix design really helped us. You spend a few thousand dollars upfront, but we've probably saved hundreds of thousands of dollars on a few projects."

Schram agreed and discussed his agency's methods for designing CIRs. Its first step is to analyze the existing pavement. "The best way to get RAP is by milling," he said. "We try to get 50 feet in three locations. If we can't get that, we fall back on cores." He listed the following criteria for CIR done with foam:

1. Determine optimum foaming characteristics.
   - Objectives: expansion ratio of 10:1 and 10 seconds half-life
   - They use two binders: PG 52-34 and PG 46-34
   - Temperature range: 280°F to 320°F
   - Water injection is between 1.5% and 3.5%
2. Compare specimens with four different foamed AC contents: 1.5%, 2.0%, 2.5%, and 3.0%.
3. Compact specimens with 45 gyrations from a Superpave gyratory compactor.
4. Optimize AC foam content based on indirect tensile strength results.

When emulsion is used, he said, they specify either HFMS-2s (for high-volume roads) or CSS1 (for other projects). Nominal coverage is 0.3 gallon/yd2, which is adjusted in the field with advice from the contractor.

An FDR project in Washington County, Minnesota (photo: Henry Grothaus)

**IDOT's CIR specifications**

Based on IDOT's projects over many years, Schram summarized the department's current CIR specifications:

- Mix design
  - Foam: 0.0011 tons/yd2-in— but we adjust in the field
  - Emulsion: 0.30 gallons/yd2-in— but we adjust in the field
  - CIR allowed May 1 through October 1 with temps 60°F and rising (Schram: "I get calls on April 20 or 25 every year asking if they can start. If you're doing CIR over concrete, there's little risk so you can go ahead. But for high-priority jobs, you're likely to have much greater success if you wait until July—until the sub-base dries out a little bit.")
- Quality assurance using a nuclear gauge
  - 94% density for primary roads—(Schram: "We don't expect 95 or 96 percent like HMA. We don't want it that way because it's a stress relief project.")
  - 92% density for secondary roads
- Overlay
  - <2% moisture (or 0.3% of residual moisture)
  - 14 calendar days to complete overlay—any damage up to the 14 days is on IDOT; if the first lift isn't on by 14 days, any damage due to traffic is at the contractor's cost.

**Cost comparison between foam and emulsion**

Schram presented the cost history shown in Table 3 for the period 2/2010 to 2/2011 and noted that the cost ranges for foam and emulsion are comparable.

**Conclusions**

- Stabilized CIR and FDR are cost-effective rehabilitation options that can be used on roads with a wide range of traffic volumes.
- Mix design procedures for these materials have been developed over 7 to 10 years and have a good track record.
- Do your homework and you won't have to blame the technology!

Table 3. IDOT Costs of CIR, 2/2010 to 2/2011

| Foam | | Emulsion | | Cost of CIR Scarification Alone |
|---|---|---|---|---|
| $530/ton | $0.58 – $0.70 per yd2-in | $1.88/gal | $0.49 – $0.66 per yd2-in | $1.30 – $2.10/yd2 |

# Session 4: PCC Pavement Rehabilitation

Moderator: Curt Turgeon, Minnesota Department of Transportation

## Michigan's Unbonded Overlay Experiences

Mike Eacker, Michigan Department of Transportation

The Michigan DOT has used unbonded concrete overlays to rehabilitate concrete and composite pavements since 1984—23 projects totaling 240+ centerline miles, Mike Eacker said. One project constructed in 1984 was reconstructed in 2003, while another built in 1984 is still in service. The remaining 21 projects are from 1990 to the present. Based on Michigan's condition measure for modeling performance, the result for unbonded overlays is a service life of 21 years, including one maintenance cycle.

Eacker then discussed lessons learned. One lesson is the need for a drainable HMA separator layer. Existing dense-graded HMA and shoulder gravel had stopped the drainage path, and water had been sitting on the separator layer, eroding the HMA and causing edge distresses. "Make sure the drainage path is clear," he said.

Another lesson is that less pre-overlay repair is needed. MDOT has traditionally been very aggressive with repairing all distresses in concrete pavement work, Eacker said, but it found that the same level of repair work for overlays isn't needed, which could save money without loss of performance. Now only the most severe cracks/joints are repaired prior to the overlay, he said.

Eacker also discussed a research project—"Improved Performance of Concrete Overlays"—under way by the University of Michigan; it was initiated in October 2009, and completion is expected in 2012. The objectives are to study existing concrete overlay distresses and recommend changes to pavement design and construction practices.

Eacker closed his presentation with a review of local agency work. Whitetopping has been used in more than 45 locations. The first project (1996) is still in service, in good condition; 96 percent are still in service, most in good or very good condition. Thin unbonded overlays were used in 14 projects. The first project is still in service; it was rehabbed for first time in 2008 after 25 years.

## Early Performance of Concrete Pavement Overlays in Minnesota

Tom Burnham, Minnesota Department of Transportation

Tom Burnham said PCC overlays are becoming more popular in Minnesota, in part because they are becoming more competitive on a first-cost basis. Standard (thick) unbonded concrete overlays have performed very well, he said. The question is: "How thin can we go?"

Unbonded overlays are used over distressed PCC pavements requiring additional structural capacity. Standard thickness is > 7.5 inches; thin is < 7 inches. Bonded overlays are used over distressed HMA pavements (also known as whitetopping). Standard thickness is 6 inches or more; thin is 4 to 6 inches; ultra-thin is 4 inches or less.

Burnham then reviewed early PCC overlay performance in Minnesota. Findings indicate good performance on standard "thick" unbonded overlays but more frequent occurrence of distresses in thin ones. There are definite limits on acceptable panel size, he said.

Whitetoppings, in a mixed application of large and small panel sizes, showed overall good performance for thin sections, he said, but demonstrated susceptibility to reflective cracking in cold climates.

## Concrete Pavement Rehabilitation Best Practices

Dan Frentress, International Grooving and Grinding Association

Dan Frentress discussed highlights of an innovative diamond-grinding approach—known as next generation concrete surface (NGCS)—tested at the MnROAD pavement research facility and on a full-scale project on I-35 in Duluth.

NGCS is designed to reduce noise levels without tires losing their grip on the road surface. It uses a combination of diamond grinding and grooving on the concrete surface to achieve this category of texture.

The NGCS surface was developed through a partnership consisting of the IGGA, American Concrete Pavement Association, Portland Cement Association, and Purdue University.

Following research at Purdue, extensive field testing and evaluation was conducted at MnROAD on both the low-volume loop and high-volume mainline.

For the Duluth project, Mn/DOT chose NGCS rather than conventional diamond grinding due to multiple road-noise complaints from a nearby hotel owner. After construction in the summer of 2010, Frentress said, road noise dropped from 107 or 108 decibels to about 99, and complaints fell to zero.

An overlay project (photo: National Concrete Pavement Technology Center)